CLAIMS

1. A method of producing a porous insulating film, comprising the step of:

introducing gas containing vapor of cyclic organic silica compounds, which have silicon and oxygen skeletons and have at least one unsaturated hydrocarbon group bound with a side chain of a skeleton, into plasma to grow a porous insulating film on a semiconductor substrate.

2. A method of producing a porous insulating film, comprising the step of:

introducing vapor of cyclic organic silica compounds, which have silicon and oxygen skeletons and have at least one unsaturated hydrocarbon group bound with a side chain of a skeleton, and vapor of straight-chain organic silica compounds, which have silicon and oxygen skeletons and have any one selected from the group consisting of hydrogen, a hydrocarbon group and a hydrocarbon oxide group bound with a side chain of a skeleton, into plasma to grow a porous insulating film on a semiconductor substrate.

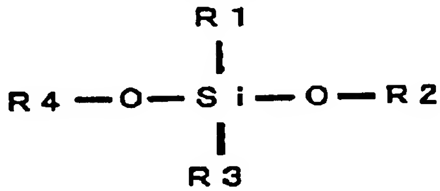
3. The method of producing a porous insulating film according to claim 2, wherein said straight-chain organic silica compounds have a structure represented by the following formula (1):

[formula 1]

$$\begin{array}{ccccccc} & & R6 & & R1 & & \\ & & | & & | & & \\ R5 & — & Si & — O — & Si & — & R2 \\ & & | & & | & & \\ & & R4 & & R3 & & \end{array} \qquad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

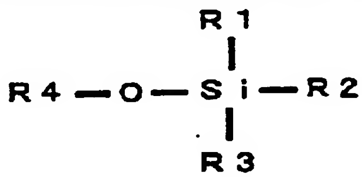
where R_1 to R_6, which may be the same or different, respectively represent any one selected from the group consisting of hydrogen, a

hydrocarbon group and a hydrocarbon oxide group; or



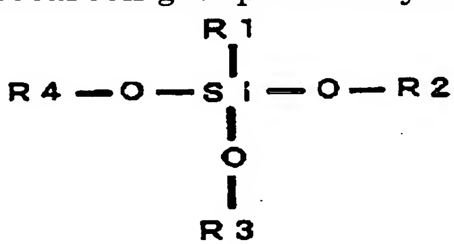
(1)

where R_1 to R_4, which may be the same or different, respectively represent any one selected from the group consisting of hydrogen, a hydrocarbon group and a hydrocarbon oxide group; or



(1)

where R_1 to R_4, which may be the same or different, respectively represent any one selected from the group consisting of hydrogen, a hydrocarbon group and a hydrocarbon oxide group; or



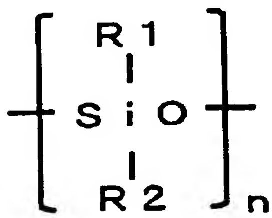
(1)

where R_1 to R_4, which may be the same or different, respectively represent any one selected from the group consisting of hydrogen, a hydrocarbon group and a hydrocarbon oxide group.

4. The method of producing a porous insulating film according to claim 2 or 3, wherein a supply ratio of said cyclic organic silica compounds to said straight-chain organic silica compounds is changed during film formation.

5. The method of producing a porous insulating film according to any one of claims 1, 2 and 4, wherein said cyclic organic silica compounds are cyclosiloxane monomers represented by the following formula (2):

[formula 2]

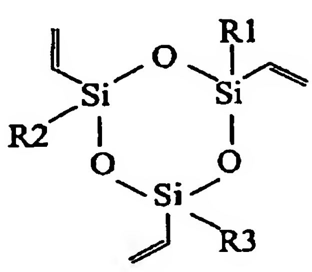


(2) Cyclosiloxane monomer

where R_1 and R_2 are respectively any one of the group consisting of hydrogen, an alkyl group, an alkoxide group, an amino group, alkene, alkyne, a phenyl group and a phenol group, provided that R_1 and R_2 may be the same or different, provided that at least one of the side chain groups is an unsaturated hydrocarbon group, and n is an integer of 2 or more.

6. The method of producing a porous insulating film according to claim 5, wherein said cyclic organic silica compounds are trivinylcyclotrisiloxane derivative monomers represented by the following formula (3):

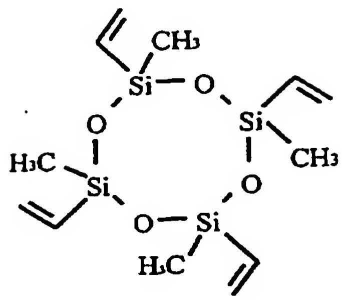
[formula 3]



(3) Trivinylcyclotrisiloxane derivative

7. The method of producing a porous insulating film according to claim 5, wherein said cyclic organic silica compound is tetravinyltetramethylcyclotetrasiloxane monomers represented by the following formula (4):

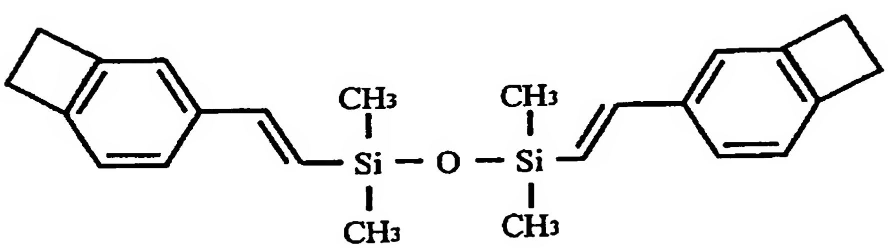
[formula 4]



(4) Tetravinyltetramethylcyclotetrasiloxane

8. The method of producing a porous insulating film according to any one of claims 2 and 4, wherein said cyclic organic silica compounds are tetravinyltetramethyl-cyclotetrasiloxane monomers represented by the formula (4) and said straight-chain organic silica compounds are divinylsiloxanebenzocyclobutene monomers represented by the following formula (5):

[formula 5]



(5) Divinylsiloxanebenzocyclobutene

9. The method of producing a porous insulating film according to any one of claims 1 to 8, wherein said plasma is plasma of rare gas.

10. A semiconductor device according to any one of claims 1 to 9, wherein said plasma is plasma of mixture gas of rare gas and oxidizer gas or hydrogenated silicon gas.

11. A porous insulating film produced by the method of producing a porous insulating film according to any one of claims 1 to 10.

12. The porous insulating film according to claim 11, comprising at least silicon, carbon, oxygen and hydrogen and having a Raman spectrum corresponding to at least three-membered silica skeleton in the Raman spectroscopic analysis.

13. The porous insulating film according to claims 11 or 12, wherein ratios of elements in the film is: O/Si = 0.8 to 1.2, C/Si = 1.5 to 10.0 and H/Si = 4.0 to 15.0.

14. The porous insulating film according to claim 11, 12 or 13, wherein the diameter of pores contained in the film is 3 nm or less.

15. The porous insulating film according to any one of claims 11 to 14, wherein at least a part of pores contained in the film have almost the same diameters as a skeleton of said cyclic organic silica compounds.

16. A semiconductor device using the porous insulating film according to any one of claims 11 to 15 as a layer insulating film of a multilayer wiring.

17. The semiconductor device according to claim 16, wherein in the vicinity of a interface between the porous insulating film and a non-porous insulating film, a relative concentration of carbon atom in at least the porous insulating film changes stepwise or continuously.

18. The semiconductor device according to claim 17, wherein said straight-chain organic silica compounds have a structure represented by said formula (1).

19. The semiconductor device according to claim 16 or 17, wherein said cyclic organic silica compounds are cyclosiloxane monomers represented by said formula (2), where R_1 and R_2 are any one selected from the group consisting of hydrogen, an alkyl group, an alkoxide group, an amino group, alkene, alkyne, a phenyl group and a phenol group, provided that R_1 and R_2may be the same or different, provided that at least one of side chain groups is an unsaturated hydrocarbon group, and n is an integer of 2 or more.

20. The semiconductor device according to claim 19, wherein said cyclic organic silica compounds are tetravinyltetramethylcyclotetrasiloxane monomers represented by said formula (4).

21. The semiconductor device according to claim 19, wherein said cyclic organic silica compounds are trivinylcyclotrisiloxane derivative monomers represented by said formula (3).

22. The semiconductor device according to claim 18, wherein said straight-chain organic silica compounds are divinylsiloxanebenzocyclobutene monomers represented by said formula (5).